Free Space Optical Link Utilizing a Modulated Retro-Reflector Intended for Planetary Duplex Communication Links between an Orbiter and Surface Unit

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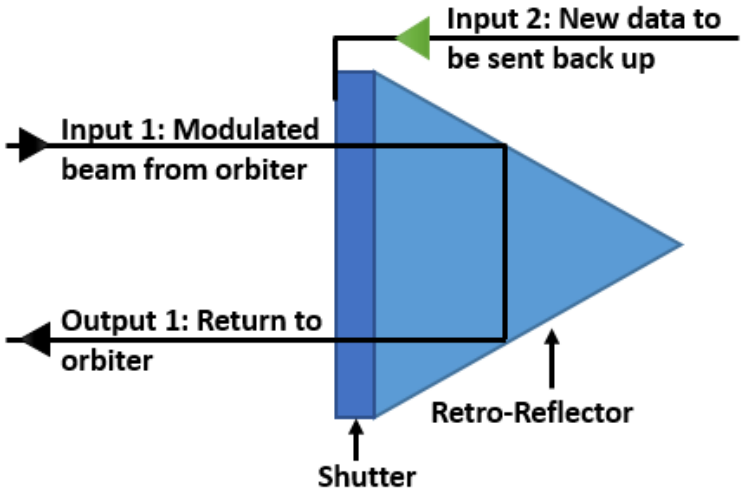
Agenda

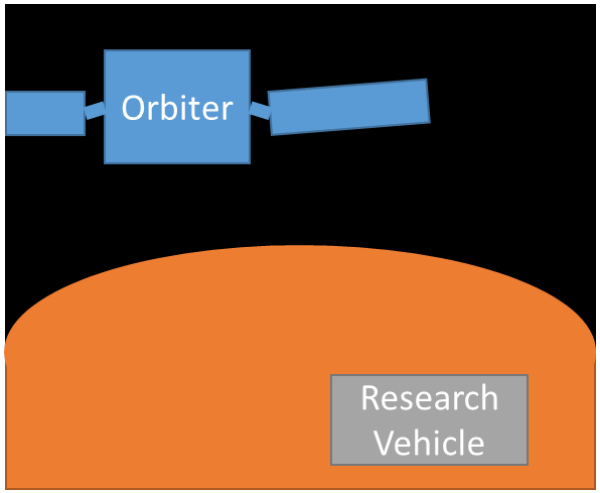
1. **Introduction**
2. **Proposed scenario**
3. **Modulation overview**
4. **Simulation - to test the proposed scenario**
5. **Experimentation - to test the modulation**
6. **Conclusions**

The Beginning

- **Why optical communications instead of radio frequency (RF)?**
- **How did we optically communicate before?**
- **Why use a modulated retro-reflector (MRR)?**
- **Why do we care?**

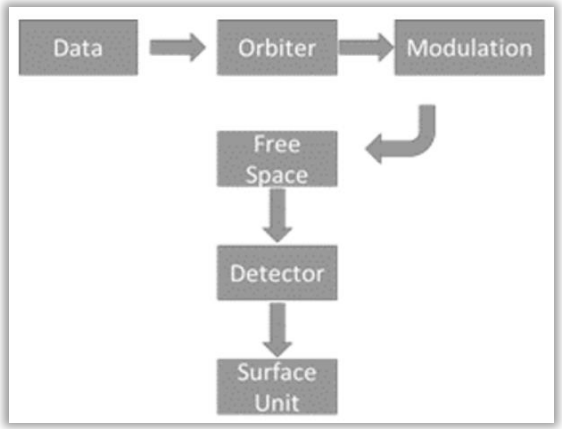
Typical Case



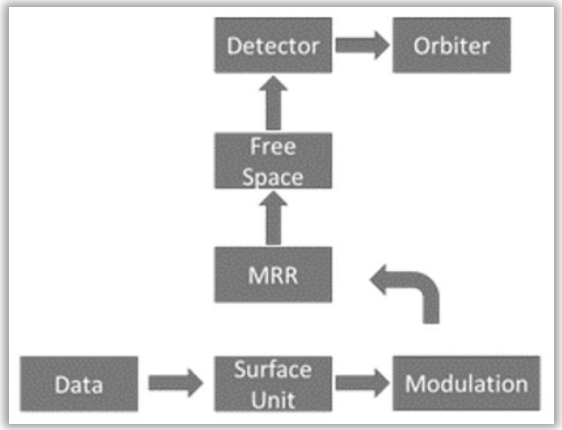


My Proposal

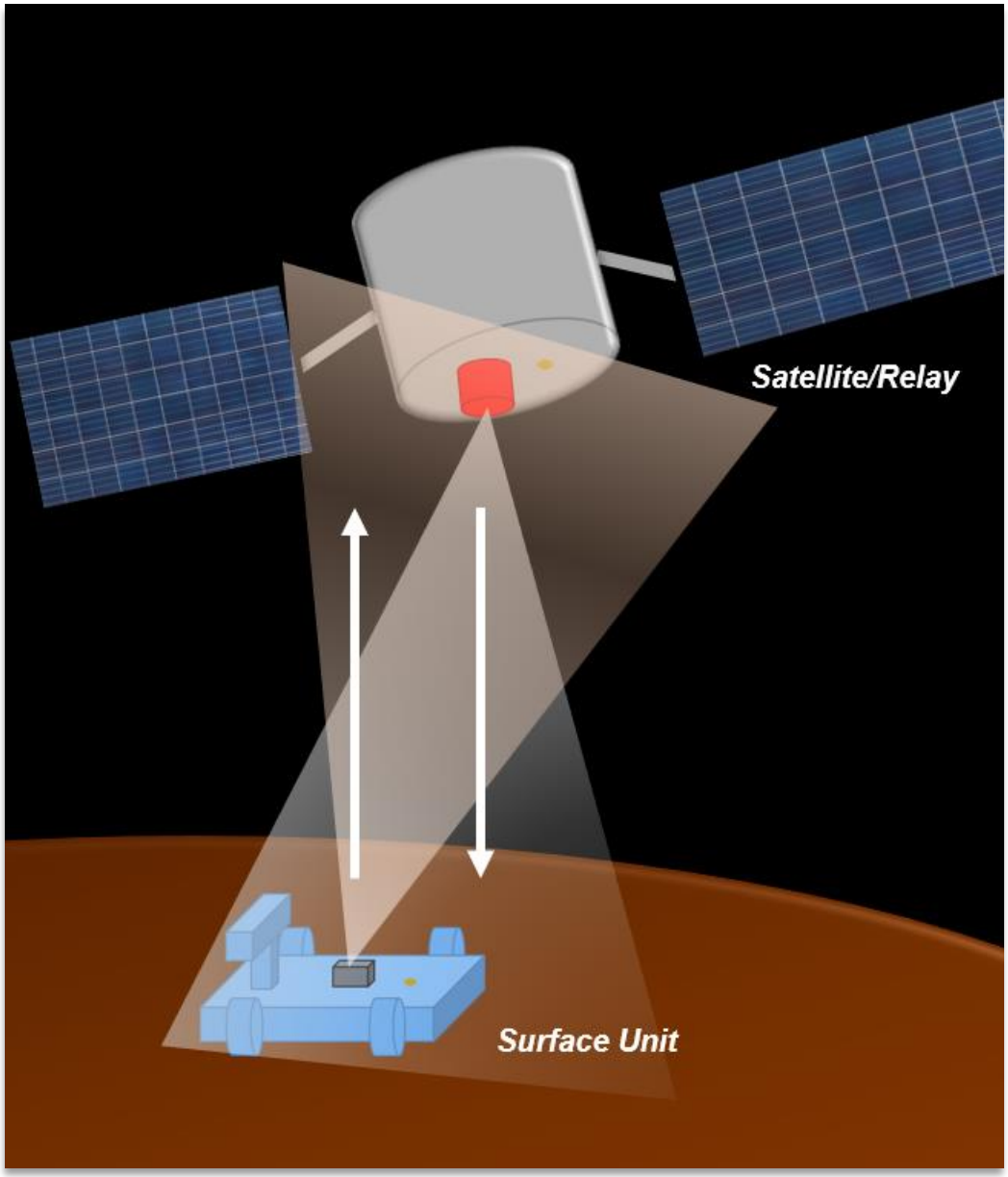
- **Let's say….Mars**
- **Orbiter contains the laser, rover contains the MRR**



Orbiter System

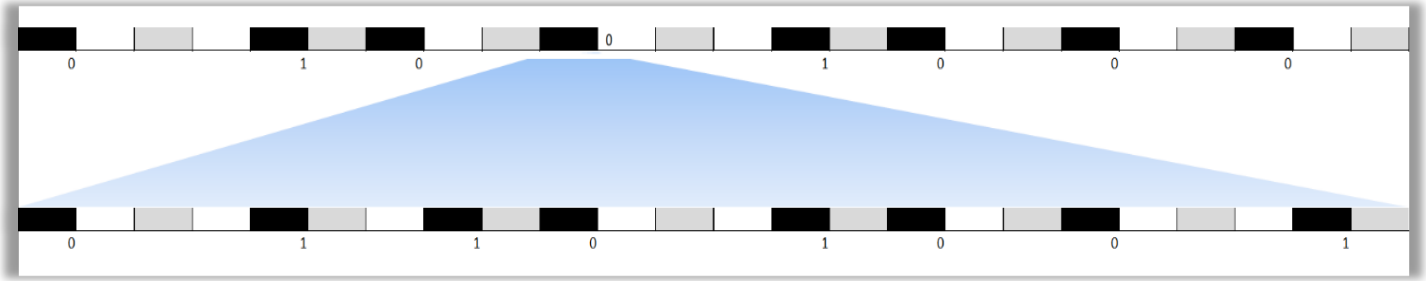


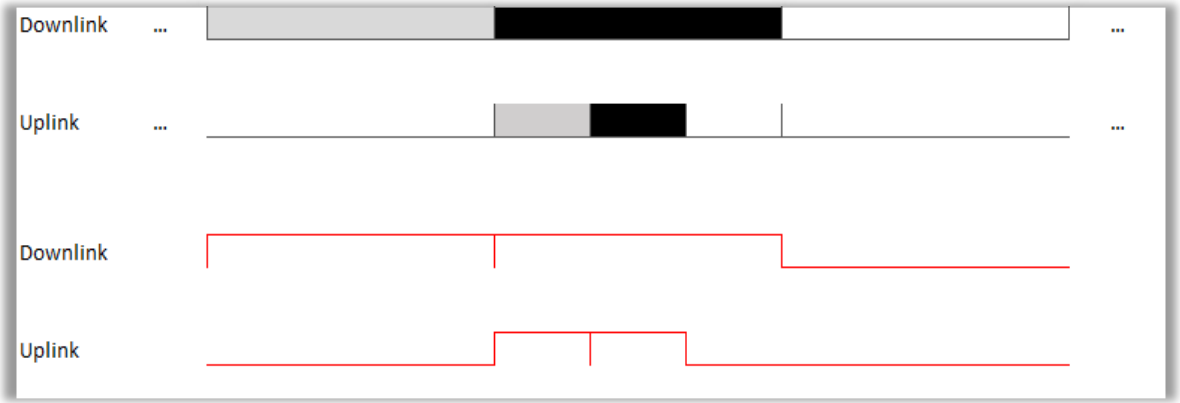
Surface Unit System



How to Modulate Our Beam

- **Keep it simple:**
  - Pulse Position Modulation (PPM)
- **But nested PPM…with a guard time slot**



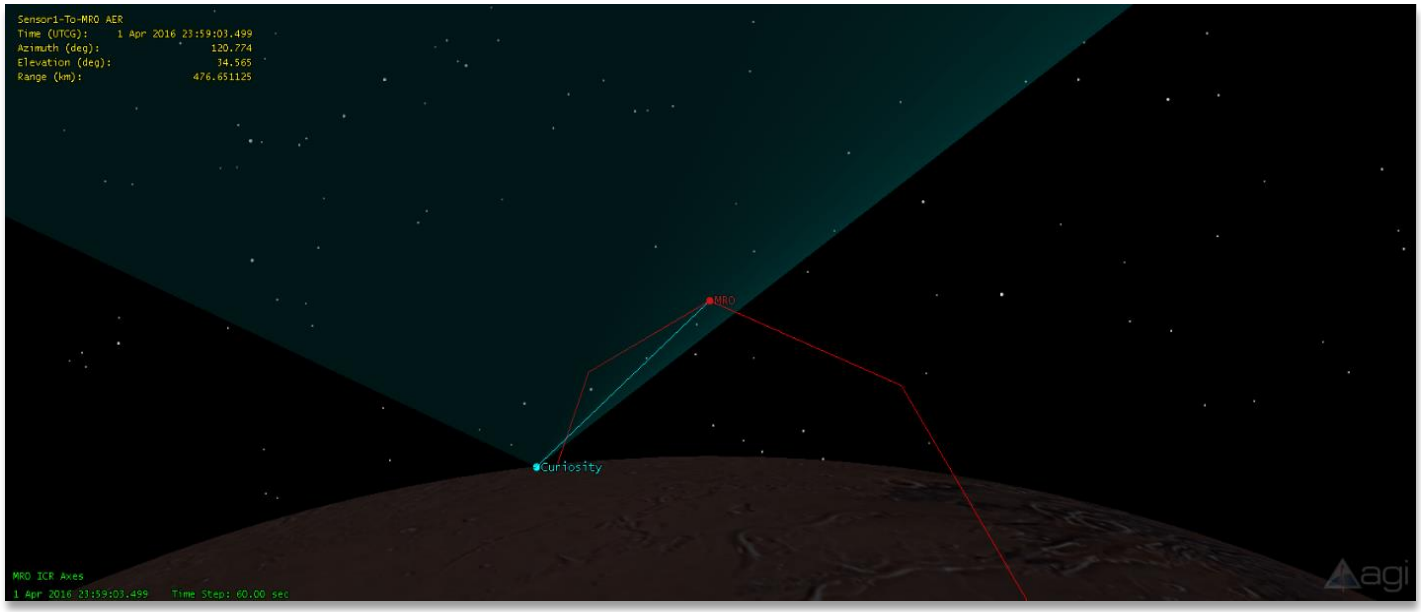


Let Us Simulate

- **Components**
  - 1550 nm laser
  - Avalanche photodiode detectors (gain of 100)
- **Link Budget Values**
  - Target Error Rate 10^{-6} BER
  - Planetary irradiance: 0.00874 W/cm^2/sr/µm
- **Use Mars Reconnaissance Orbiter (MRO)**
  - BSP files of MRO's aerobreaking

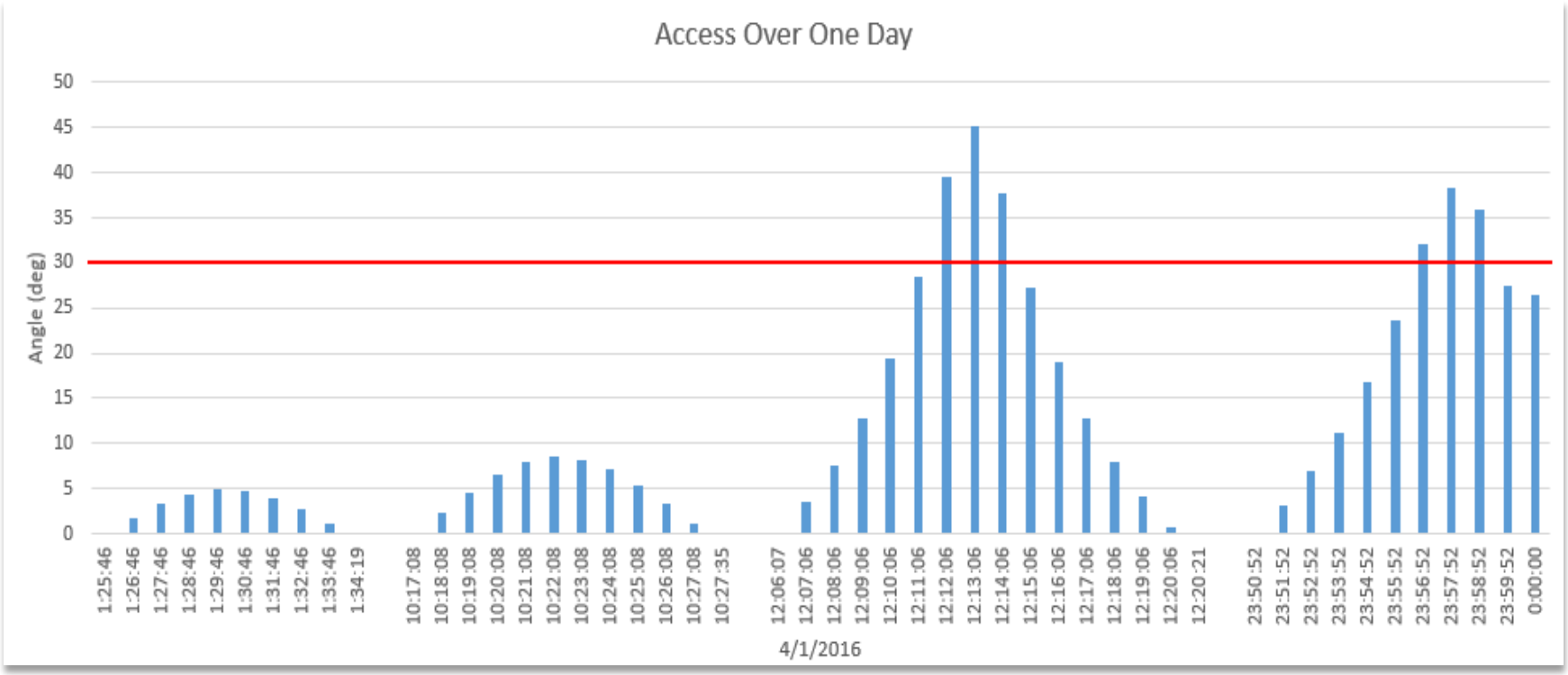
  - Aperture detector diameters: 10 cm and 2 cm
  - MRR aperture diameter: 2 cm
  - MRR surface roughness: 2 cm

  - Sky irradiance: 0.0035 W/cm^2/sr/µm
  - Downlink data rate: 150 kbps
  - Uplink data rate: 300 kbps



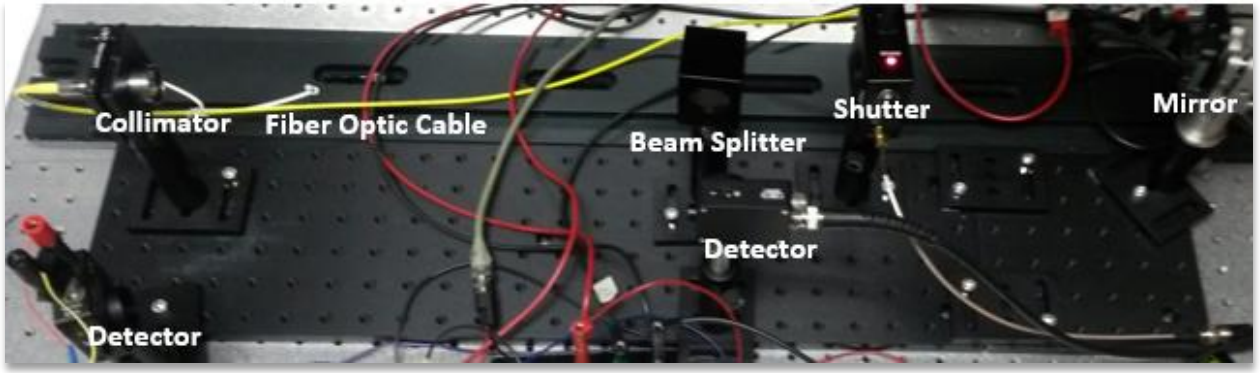
Some Results

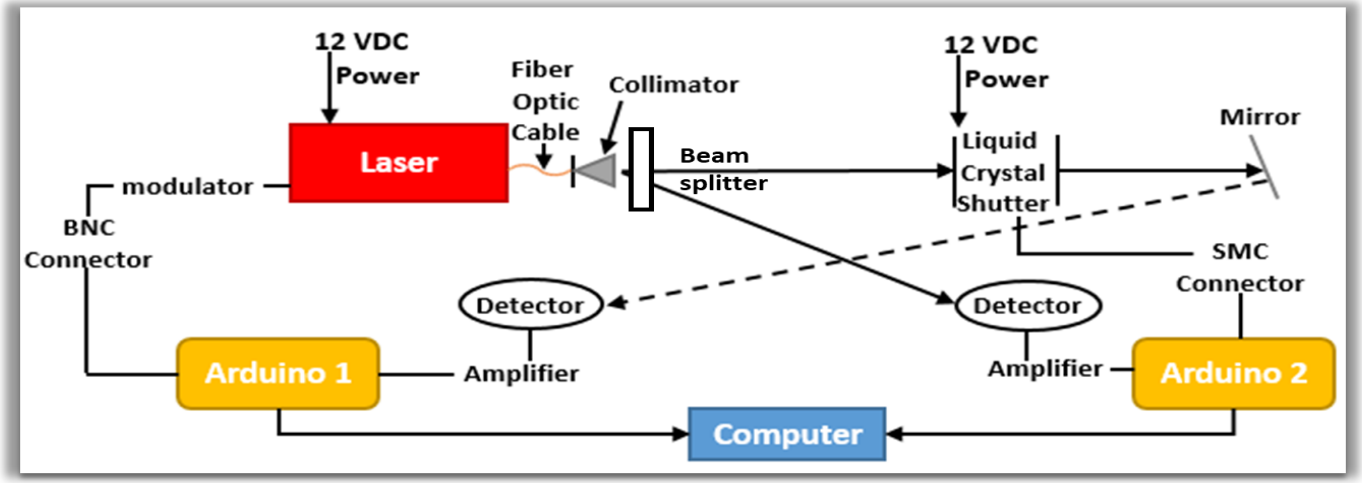
- **45.85 total line-of-sight minutes**
- **Calculations require 30-degree limit**
  - ~6.55 minutes
- **Some points in the data had enough margin to increase the data rate**



Testing Our Modulation

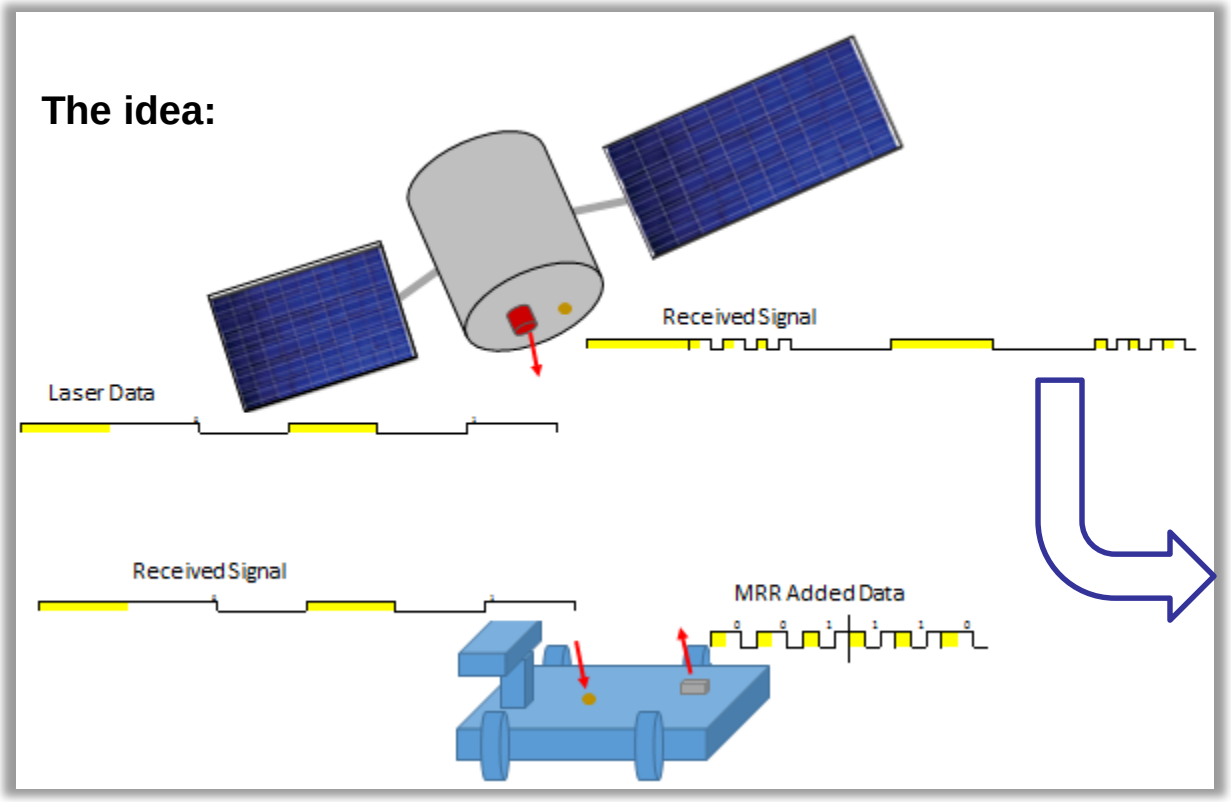
- **Component changes from the simulation**
  - 635 nm (red) laser
  - MRR is mirror and liquid crystal shutter
  - Beam splitter
  - Arduino Uno and Mega 2560

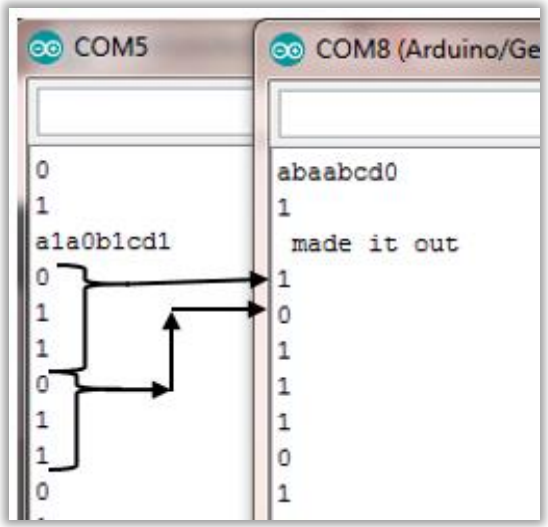




Proof

- **Laser sends 1011**
- **Surface Unit adds within each bit three bits: 011**





Rover **Orbiter**

Conclusions and Future Work

- **Two parts of the system were successful in their test**
  - Proposed scenario is possible, i.e. proved by simulation
  - Modulation scheme is feasible, i.e. proved by experimentation
- **Proposed scenario was calculated at less than optimal conditions**
  - Still performed better than Electra on Curiosity in most cases
  - Higher data rates are possible!
- **Ideal for small mobile low power situations**

Future Work:

- **See how our contact times for communication improve lowering down to Electra**
- **Check out other modulation schemes that might be better optimized for this communication**

Any Questions?